

Overview

The purpose of this unit is to introduce students to the LabVIEW™ for LEGO® MINDSTORMS® programming language and LEGO MINDSTORMS robotics. This guide describes how to create a program using LabVIEW for LEGO MINDSTORMS software and how to operate and upload programs onto the NXT Brick. It also describes some NXT functions in LabVIEW for LEGO MINDSTORMS software, such as the Motor Control and Wait For functions. Students will create, deploy, and test programs on the robots that have been created.

At the end of this lesson, students should be able to:

- Create a new Robot Project targeted to the NXT Brick in LabVIEW for LEGO MINDSTORMS software.
- Connect to the NXT Brick via Bluetooth® or USB.
- Understand how the Schematic Editor works.
- Create a program using LabVIEW for LEGO MINDSTORMS software that instructs the robot to move forward and stop.
- Download programs onto the NXT Brick device.

Basics of LabVIEW for LEGO MINDSTORMS Software

LabVIEW for LEGO MINDSTORMS is a programming language like C++, Java, Visual Basic, or ROBOTC®. It is a little different from a traditional text-based programming language because it is entirely graphical. LabVIEW for LEGO MINDSTORMS is composed of blocks on the screen. These blocks are connected with wires. The blocks include functions, inputs, and outputs.

When LabVIEW for LEGO MINDSTORMS software is launched, the Getting Started window appears. Use this window to access various resources including online help, example programs, and discussion forums. The Getting Started window can also be used to open any programs that have recently been worked on. Use the Getting Started window to start working on a new program. Click the **Create Program** button shown in Figure 1.

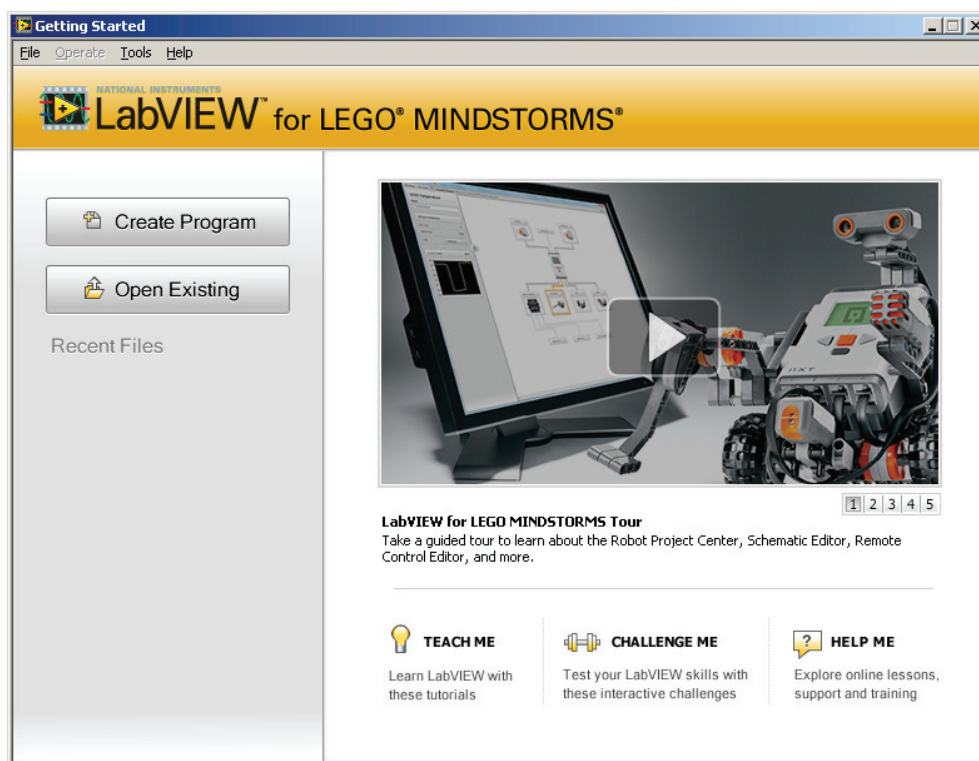


Figure 1. Getting Started Window

After clicking **Create Program**, the options **Robot Project** and **Virtual Instruments** will appear. Notice the term "VI." VI is an acronym for Virtual Instrument. Basically, a VI is a LabVIEW for LEGO MINDSTORMS program. Additionally, ".vi" is the file extension of a program when it is saved in LabVIEW for LEGO MINDSTORMS software.

In LabVIEW for LEGO MINDSTORMS software select **Robot Project** and click **Blank Robot** from the **New Program** screen, as shown in Figure 2.

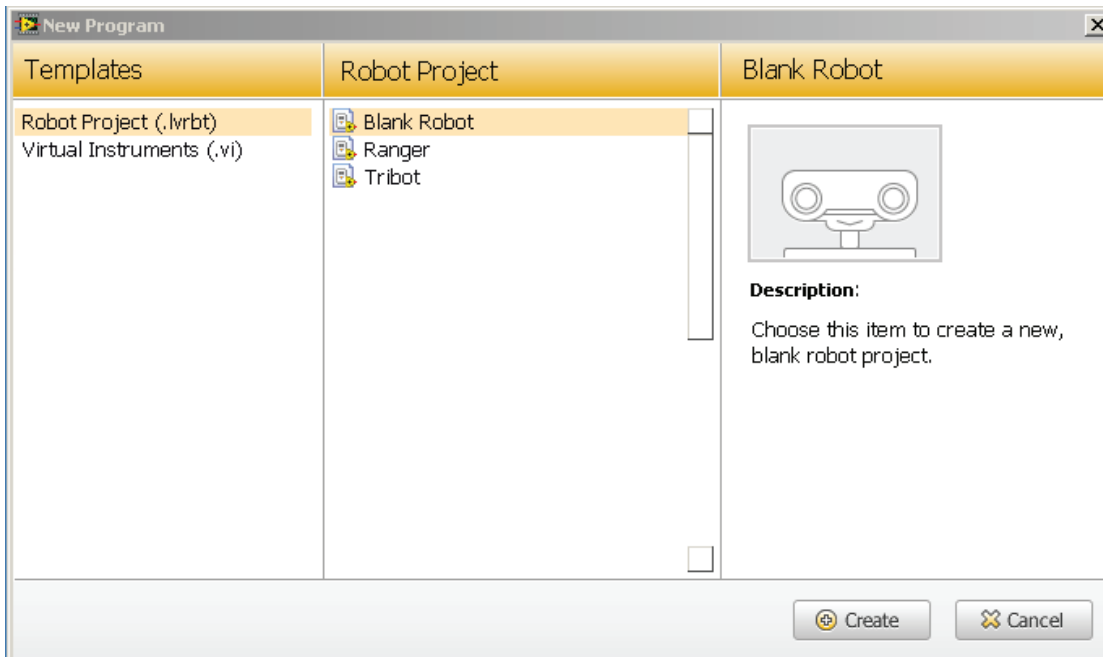


Figure 2. Creating a New Program

Click **Create** to open the **Specify Robot Project Path** window where the **Robot Project** name and folder path can be set. Name the Robot Project and choose a file path. Click **Create** in this window to open the **Robot Project Center**. The Robot Project Center is the starting point for all LabVIEW™ for LEGO® MINDSTORMS® projects and programs. It contains links to choose which NXT Brick will run programs, links to specify the setup of the robot and specify motor and sensor details, as well as links to create new VIs that will be a part of the current robot project. It also lists the Robot Files that are a part of the project and can be used to manage these files. This is shown in Figure 3.

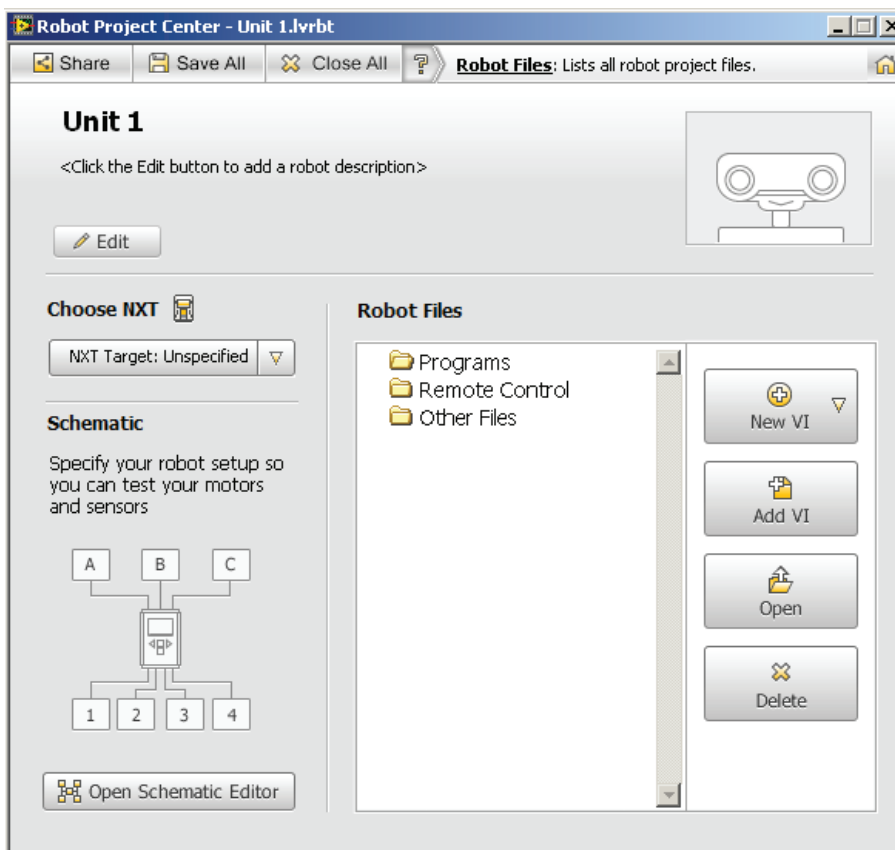


Figure 3. The Robot Project Center

Choosing the NXT Brick

To specify the robot build in the Schematic Editor, we first need to look at the NXT Brick in detail.

The NXT Brick is the brain of a LEGO® MINDSTORMS® robot. It boasts a powerful 32-bit microprocessor and flash memory. It is shown in Figure 4.

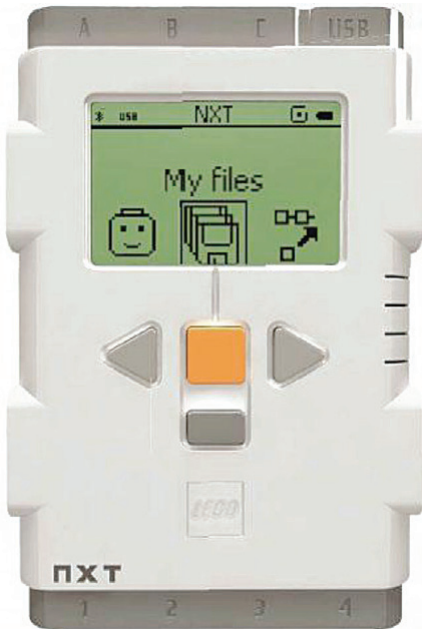


Figure 4. NXT Brick

The NXT can receive input from up to four sensors and control up to three NXT servo motors via its seven ports. It also has an LCD display and four buttons. The buttons are used to navigate through the NXT menus. The NXT Brick is powered by six AA batteries or a rechargeable battery pack.

The two gray arrow buttons are used to navigate through the NXT Brick's menus. The orange button is used to select objects from the menu, and the dark gray rectangle button is used to end a program or navigate to the main menu on the NXT Brick.

Connect the computer to the NXT Brick using USB or Bluetooth®. Start by connecting one end of the USB cable to the NXT Brick and the other to the computer's USB port. Next, press the orange button to turn on the NXT Brick. The first time an NXT Brick is connected to a computer, it is important to be patient because the operating system can take a few minutes to install the drivers. After the connection has been made, the operator needs to tell LabVIEW™ for LEGO MINDSTORMS software where to find the NXT Brick. Click the arrow below the **Choose NXT** option in the **Robot Project Center** and click **Find NXT**. This will open a window similar to the one shown in Figure 5.

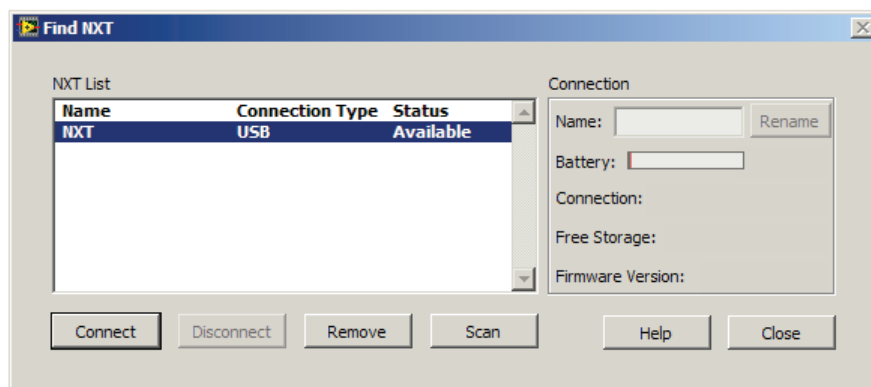


Figure 5. Finding the NXT Brick

Because the NXT Brick has already been connected via USB, it will be listed. Click it once to highlight it and click **Connect** to link it to LabVIEW for LEGO MINDSTORMS software. The window updates to show the name, battery level, and other information about the NXT Brick that has been connected. This is shown in Figure 6.

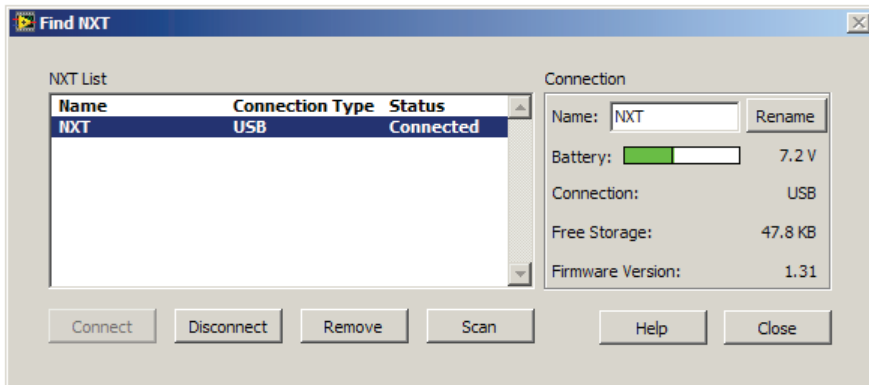


Figure 6. Established Connection with NXT

If a USB connection is going to be used, then the brick is now connected. Click **Close** to continue. Otherwise, connect to the NXT Brick via Bluetooth®. Connecting a computer with the NXT Brick via Bluetooth® is more convenient than connecting using a USB cable because it eliminates the use of cables. To connect to the NXT Brick via Bluetooth, ensure that either the computer has built-in Bluetooth capabilities or that there is a USB Bluetooth adapter installed. Enable Bluetooth from the computer or the Bluetooth adapter.

Also ensure that Bluetooth is enabled on the NXT Brick. To do this, turn on the NXT Brick and select **Bluetooth** from the main menu, as shown in Figure 7.



Figure 7. Selecting Bluetooth from the Main Menu

Ensure that Bluetooth has been activated by selecting the **On/Off** icon and selecting **On**. After Bluetooth has been enabled, the NXT will return to the main menu. Ensure also that the NXT Brick's visibility has been enabled so that the computer is able to seek it. To do this, go into the **Bluetooth** menu again, select **Visibility**, and then select **Visible**.

Now that Bluetooth has been activated on the computer and the NXT Brick, connect to the NXT Brick via Bluetooth. To connect to the NXT, follow a similar procedure to when connecting via USB. Click the **arrow** next to **Choose NXT** and click **Find NXT**. The same window seen earlier in Figure 5 will be displayed. This time, click **Scan** to search for Bluetooth devices. Notice that LabVIEW™ for LEGO® MINDSTORMS® will search for Bluetooth devices, as shown in Figure 8.

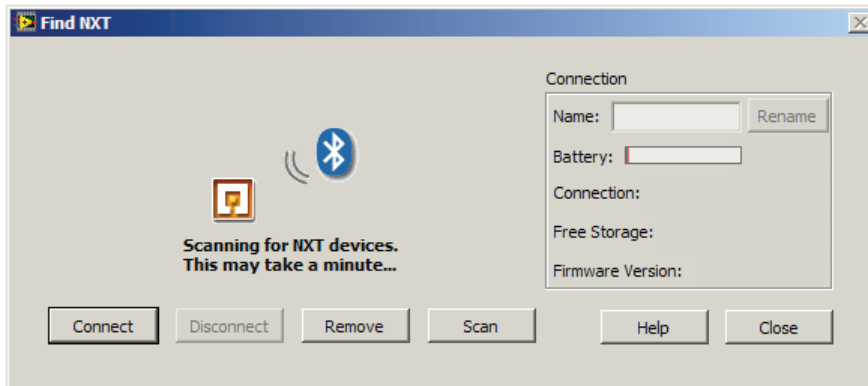


Figure 8. Searching for Bluetooth® Devices

After about 10-15 seconds, the NXT Brick will be found, as shown in Figure 9.

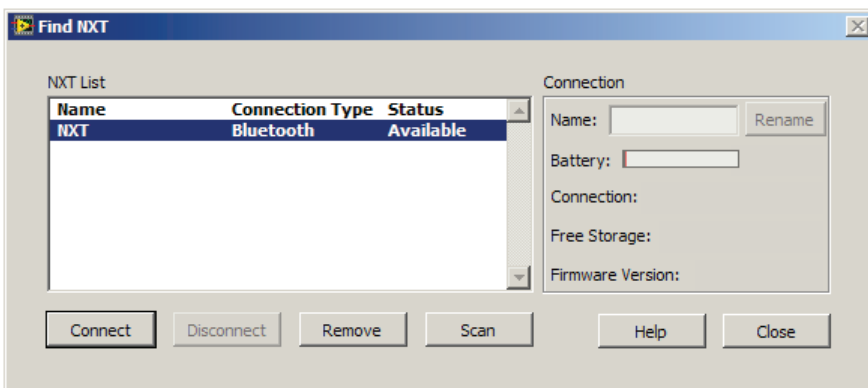


Figure 9. NXT Found Via Bluetooth

Click the name of the NXT Brick once to highlight it and then click **Connect**. If this is the first time this NXT Brick is connecting to the computer, it will prompt to enter a passkey before the NXT Brick can pair with the computer. This window is shown in Figure 10.

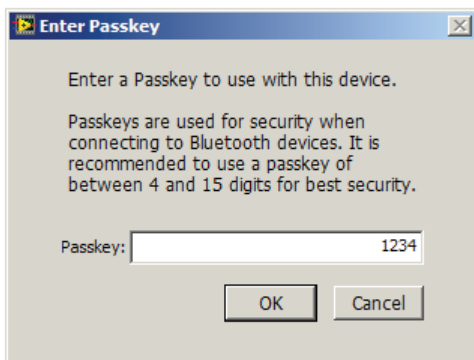


Figure 10. Passkey Prompt

Enter **1234** as the passkey and select **OK**. Then there will be a beep and a prompt to enter a passkey on the NXT Brick. Again, select **1234** by navigating right and left with the gray arrow buttons on the NXT Brick and selecting with the orange button. After entering **1234**, navigate to the checkmark icon and select it with the orange button. This is shown in Figure 11.



Figure 11. Entering Passkey on the NXT Brick

After this is complete, the operating system will take a few moments to form a connection to the NXT Brick via Bluetooth®. It will now be possible to wirelessly compile programs onto the NXT Brick.

The Schematic Editor and the NXT Brick

To configure the program and select the robot setup, employ the Schematic Editor. The Schematic Editor can be used to specify the robot setup as well as test it. To do this, click **Open Schematic Editor** in the **Robot Project Center**.

The Schematic Editor is a useful tool that helps to analyze the connections that have been made and can also be used to test the various motors and sensors connected to the NXT Brick. It is easy to use and helps to visualize the connections.

To add a LEGO® MINDSTORMS® servo motor, which is all that will be used in this unit, click the arrow next to the Motor Port to which the motor has been attached. Note that LEGO MINDSTORMS motors can be added only to output Ports A, B, and C of the NXT Brick. This is shown in Figure 12.

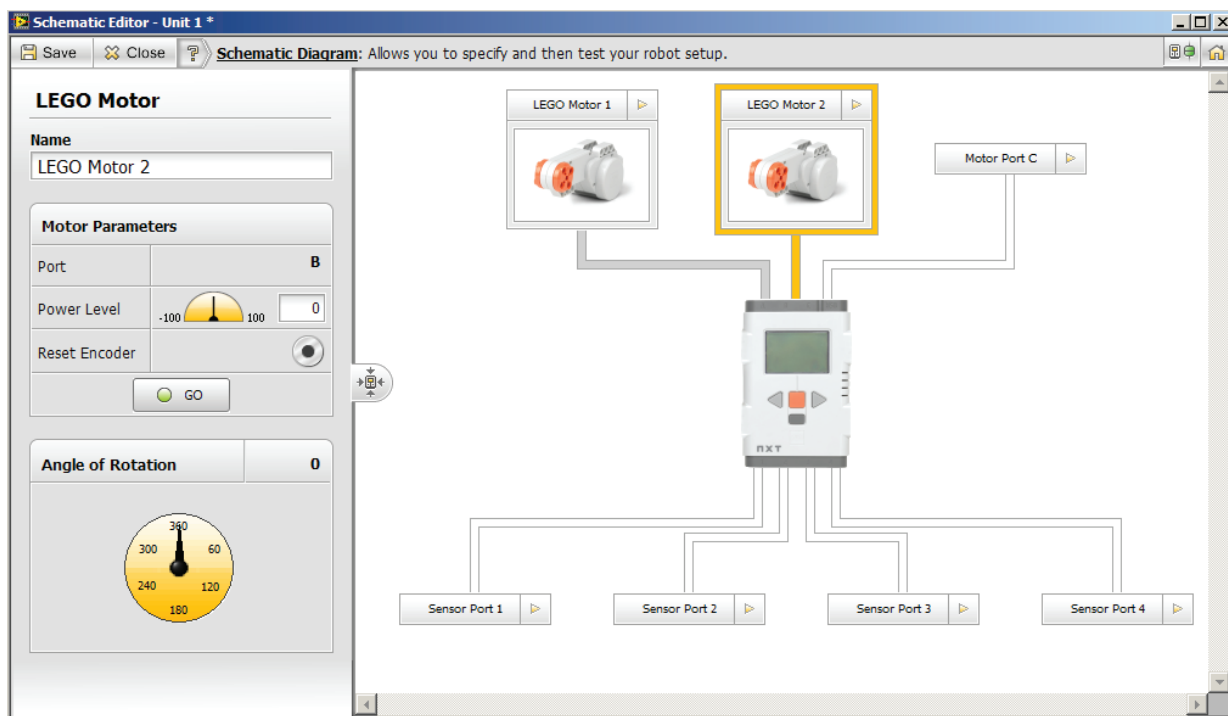


Figure 12. Adding Motors in the Schematic Editor

After the changes have been made to the Schematic Editor, click **Save** and then click **Close**. The Robot Project Center will open up again.

Creating a New VI

The next logical step is to create a VI. To do this, click **New VI**. A drop-down menu will appear where it can be specified whether this VI is targeted to the NXT Brick or the computer. In most cases, the desired configuration will be for the program to be able to run on the NXT Brick, without the computer connected, so click **VI for NXT Target**.

Enter a name for the VI, and then click **Create**. After this has been done, two new windows will open. One is called the front panel, and the other is called the block diagram. These are shown in Figure 13.

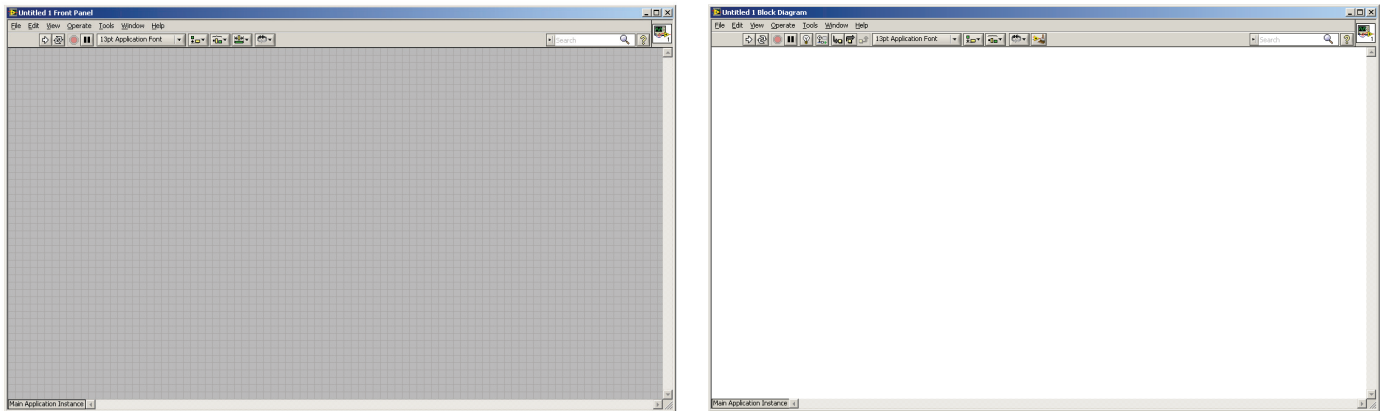


Figure 13. Front Panel (left) and Block Diagram (right)

The front panel is similar to the front panel on the NXT Brick. This is where buttons, displays, and indicators can be seen. It is the user interface of the program. The block diagram is where programming is performed. This is where code will go. The code tells the hardware what to do and when to do it.

The items placed on the block diagram are called terminals and functions. The items placed on the front panel are called controls and indicators. An interesting thing to note is that if the block diagram is closed, it can be accessed again from the front panel. Do this by selecting the **Window** drop-down menu and selecting **Show Block Diagram**. It can also be done by pressing **Ctrl-E**. This shortcut also enables toggling back and forth between the front panel and the block diagram. Whenever the front panel is closed, this essentially closes the VI and prompts the user to save any changes.

Creating LabVIEW™ for LEGO® MINDSTORMS® Code Using the Block Diagram

Now that the basics of how to navigate through LabVIEW for LEGO MINDSTORMS software have been covered, it's time to learn how to write code within the block diagram. Begin by writing a simple robot program that will drive forward for a certain amount of time and then stop.

Become familiar with the Functions palette from which the building blocks of the code will be accessed. Right-click the **block diagram** to bring up the Functions palette, and then select the **NXT I/O** menu. Notice that a sub-palette will be used when programming LEGO MINDSTORMS robots. This is shown in Figure 14.

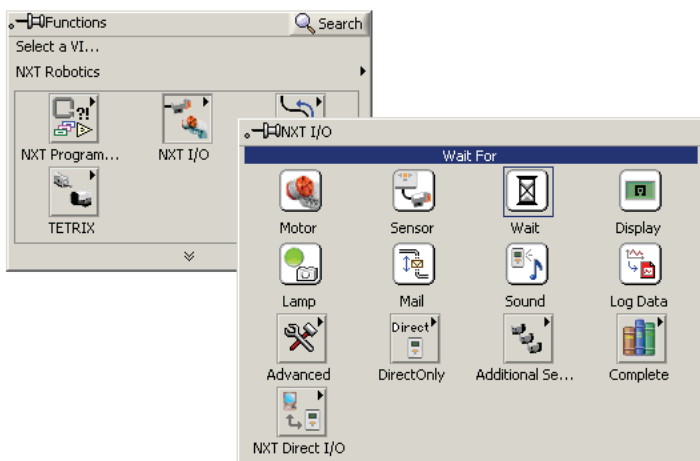


Figure 14. NXT I/O

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Explore some of the items in the NXT I/O sub-palette. Navigate to the **Help** drop-down menu, select **Show Context Help**, and then hover over these items. Use the Context Help to assist in understanding them. Alternatively, press **Ctrl-H** on the keyboard to bring up Context Help.

Hover over the **Motor Control** icon and notice that **Context Help** shows what the output and input terminals of that function do. This is shown in Figure 15.

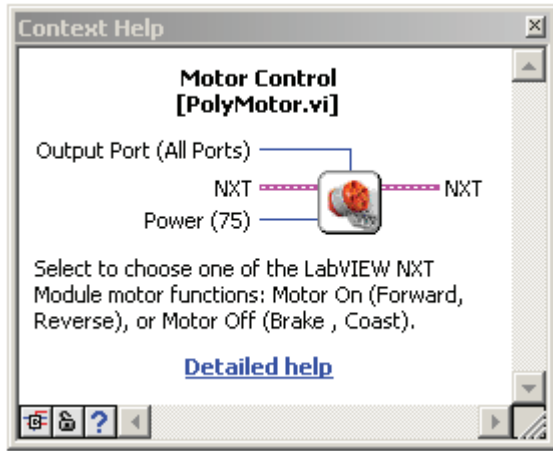


Figure 15. Motor Control

Notice that two of the terminals on this function are called NXT. One is an NXT input terminal and the other is an NXT output terminal. In a nutshell, these NXT terminals are used to sequence items together. Notice that there is a terminal for Power and one for Output Port. The Output Port terminal is where the user tells the program which motor to control. The Power terminal tells the program the speed at which the motor should spin.

Go ahead and select the **Motor Control** function and place it onto the block diagram. This is shown in Figure 16.



Figure 16. Motor Control

When selected, the Motor Control function is defaulted to moving in a forward direction. Where it says **Fwd**, there is also a selector to open a drop-down menu. Click the drop-down menu and two choices will appear: Motor On and Motor Off, as shown in Figure 17.

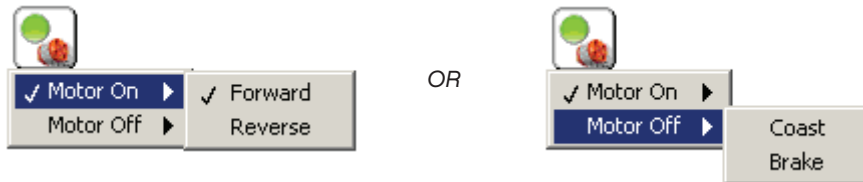


Figure 17. Polymorphic Selector Options

In the **Motor On** menu, choose to have the motor move **Forward** or **Reverse**. There is also the **Motor Off** menu, where it is possible to choose **Coast** to have the motor turn off by coasting to a stop, or choose **Brake** to immediately stop the motor.

Most of the functions will have this type of drop-down menu, called a polymorphic selector. This is a way of saying that this function can work differently in different situations. Notice that as the cursor hovers over the different options in the polymorphic menu, the **Context Help** changes to different descriptions.

In this case, the desired outcome is for the robot to move forward, so leave it in its default state: **Fwd**. To set up the motor to make the robot move forward, start by creating a constant to specify its speed. To do this, right-click over the **Power** terminal, choose **Create**, and click **Constant**. Now type a number for the speed of the motor, ranging from 0 to 100. It is important to realize that the default speed is 75, so if a speed is not selected, LabVIEW™ for LEGO® MINDSTORMS® will automatically select the speed of **75**. This is shown in Figure 18.



Figure 18. A Selected Motor Speed

Now specify which motor this function is controlling. Right-click the **Output Port** terminal, choose **Create**, and click **Constant**. This creates a constant which can select between a list of options, called an enum constant. The enum constant is wired to the terminal, as shown in Figure 19.

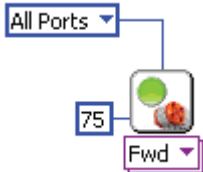


Figure 19. Port Selector

Remember that the goal of the program is to drive forward for a certain amount of time and then stop.

Now that there is a Motor On function, which will cause the robot to drive forward, the program requires a function that will wait for a certain amount of time. The Wait For function waits for a specified amount of time before letting the program continue. The **Wait For** function can be found under **NXT I/O** and by clicking **Wait**. This is shown in Figure 20.

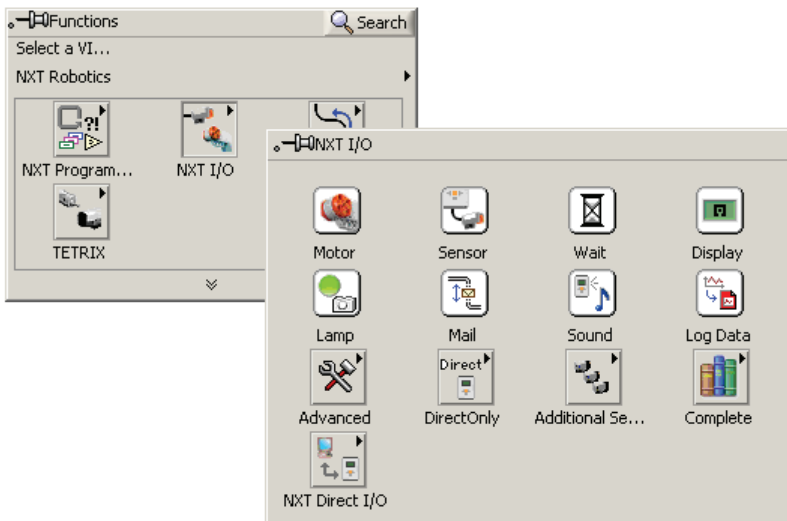


Figure 20. Location of Wait For

When placing the block, notice that it is a polymorphic function. There are many options here as shown in Figure 21.

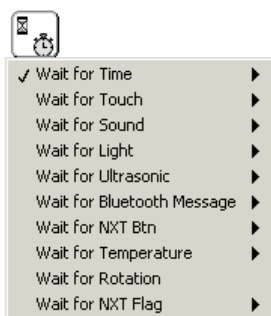


Figure 21. Wait Function's Polymorphic Selector

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The default is Wait for Time, which waits for a certain number of seconds. Using the **Context Help**, create a constant to define the delay duration of two seconds.

After this time has elapsed, the robot should stop immediately, so introduce a **Motor Brake** function. First, place a **Motor Control** function into the code. Use the polymorphic selector to select the **Motor Off** function, and then click **Brake**, as shown in Figure 22.



Figure 22. Motor Brake

Up to now, the Create Constant option defines input parameters for functions. Not only does this option create the value, but also notice that it creates a line that connects the number or port selector to the function. These lines are called wires, and wires are used by LabVIEW™ for LEGO® MINDSTORMS® to pass data between constants, functions, inputs, and outputs.

To manually wire items, bring up the **Tools** palette by clicking the **View** menu and selecting the **Tools** palette. Ensure that automatic tool selection is enabled by clicking the **LED** beside the wrench and screwdriver icon at the top of the **Tools** palette. The LED will be bright green when automatic tool selection is enabled. With automatic tool selection, the mouse pointer will change into different tools depending on the function the mouse is hovering over.

In order to make the program run in a certain sequence, the NXT input and output terminals must be wired together sequentially. With automatic tool selection enabled, click the **NXT output terminal** of the function that must run first, click again to create a wire into the NXT input of the function that must run next. Repeat this process to wire its NXT output to the NXT input of the next function. This is done until all of the functions in the sequence are wired together, input to output, as shown in Figure 23. The actual code in the blocks has been erased to focus the proper sequence the code must follow in order to work for this exercise.



Figure 23. Wiring Together a Sequence

Deploying and Running LabVIEW™ with LEGO® MINDSTORMS® Code on the NXT Brick

Now that there is a functional program, transfer it to the NXT Brick and then run it.

If the NXT Brick is being used for the first time for running VIs, it is essential that the correct firmware has been installed. To do this, select the **Tools** drop-down menu and click **NXT Terminal**. This opens a window similar to the one shown in Figure 24.

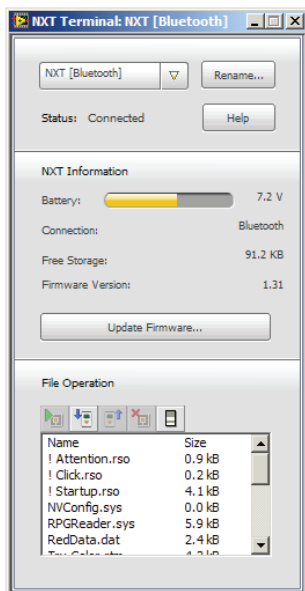


Figure 24. NXT Terminal

If there are multiple NXT Bricks connected, select which one to sync with by using the drop-down menu at the top of this window. This window shows the battery level of the NXT Brick, the amount of free space in its memory, and its firmware version. The first time an NXT Brick is run with LabVIEW™ for LEGO® MINDSTORMS® software, the firmware should be updated by clicking **Update Firmware**. However, this should only be done when connected via USB. At the bottom of this window, notice the File Operations. Here it is possible to see all of the files currently on the NXT Brick. It is a good idea to delete any old or unnecessary programs from the NXT Brick. All of the software files are in “.rx” format. Click the file once to highlight it and then click **Delete File(s)** to remove it. Delete only the .rx files. Also, click **Defragment** to clear up some memory.

Now programs can be run on the NXT Brick. On the LabVIEW for LEGO MINDSTORMS toolbar, notice that there are three buttons to run a program, each of which runs the program slightly differently. These three buttons are Run, Deploy, and Debug. These buttons are shown in Figure 25.



Figure 25. Running Programs

The Run button compiles the program onto the NXT Brick and immediately runs it. If this button is used with the code created in the lesson to make the robot move forward, LabVIEW for LEGO MINDSTORMS software compiles the software onto the NXT Brick and the robot immediately moves forward.

The Deploy button compiles and downloads the program onto the NXT Brick but does not run it until the user chooses to run it using the buttons on the NXT Brick. This is very helpful if the user wishes to compile the program using USB without having it run immediately. For example, if the program involves the robot moving, the Run button will compile and run the program, causing the robot to start moving with the USB cable still attached, whereas the Deploy button will only compile the program and, when the USB cable has been removed, run it.

The third method for running a program is the Debug option. Essentially, Debug keeps the link between the LabVIEW for LEGO MINDSTORMS program on the computer and the NXT Brick. Use this to debug the program to make sure it is working properly.

By selecting either the Run button or the Deploy button, run the program and see that the robot has moved forward for a certain amount of time and then stopped. This marks the creation and deployment of the unit's first robot program.